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ABSTRACT

This study sought to determine if logical relationships that have been clearly established in textual terms can be presented equivalently in diagrams, and, if so, what the effect might be on student comprehension when diagram technology is employed together with instructive questions. Participants in the study were 129 college students randomly assigned to 1 of 4 treatment groups. The theses of the study were that flow diagrams are a more effective presentation type for cyclical information than texts, and that each presentation type, when used in conjuction with instructive questions, will enhance the learning of verbal chains. Evaluation of comprehension tests following different types of presentations and questioning techniques indicated that flow diagrams were more effective than texts in presenting this kind of information. Also, instructive questions did not enhance the learning effectiveness of the presentation type. No significant differences were found between males and females or between different college majors. Two tables and four figures are included. (JD)

EFFECTS OF USING DIAGRAMS and TEXTS to TEACH VERBAL CHAINS: A COMPARISON of GENDER and COLLEGE MAJOR

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EFFECTS OF USING DIAGRAMS and TEXTS to TEACH VERBAL CHAINS: A COMPARISON of GENDER and COLLEGE MAJOR

Can logical relationships that have been clearly established in textual terms be presented equivalently in diagrams? If so, what is the effect on student comprehension or a learners ability to remember sequences (verbal chains) when diagram technology is employed together with instructive questions? Are there significant differences among gender and among education versus non-education majors.

According to Larkin and Simon (1987), people distinguish diagrammatic from sentential [texts] representations of information by developing alternative models of information-processing systems that are informationally equivalent and that can be characterized as sentential or diagrammatic. *Sentential* representations are sequential, like the propositions in texts. *Diagrammatic* representations are indexed by location in a plane. The theses of this study are that flow diagrams are a more effective presentation type for cyclical information than texts, and that each presentation type, when used in conjunction with instructive questions, will enhance the learning of verbal chains. The purpose of this study, therefore, was to evaluate the potential of flow diagrams and texts to teach verbal chains, and the ability of instructive questions to act as prompts or as information organizers.

Need for the Study

Research on diagrams is important for two reasons. First, most of the messages transmitted by electronic media are print oriented (Jonassen, 1982). A problem is that the effectiveness of visual materials as a component of a meaningful learning strategy is said to be obscured due to a ' for standardization among visual materials (Clark, 1983; Clark & Angert, 1980; Dwyer, 1978; Heinich, 1984). The concept of standardization among visual materials can be realized once educators are able to select visual materials based on their attributes. The attributes of diagrammatic presentations are relatively well defined and the benefits of using instructive questions is also outlined rather implicitly in research literature. However, no categorical recommendation about the use of flow diagrams can be made at this time because of the lack of diagram theory development and subsequent research in this area. Further, research should help clarify the potential utility of flow-diagram-based instruction. According to Holliday (1976), "if the terminal behavior includes concept attainment, the placement of a flow diagram with questions before or after a verbal

discussion of the concepts might prove to constitute an effective instructional package" (p. 75). Therefore, it is recommended that instructional designers more seriously consider and investigate the use of flow diagrams with instructive questions as an instructional medium.

Charts, graphs, and diagrams comprise a family of graphic forms that have in common the attributes of abstraction and the exploitation of space. Charts illustrate relationships among categorical variables; graphs show relationships between individual variables; and diagrams describe whole processes often at levels of greater complexity than charts or graphs (Winn, 1987). Holliday (1976) noted that the basic difference between flow diagrams and textual descriptions was the manner of linking the sequential chains together. In flow diagrams, the connecting words which provide structural coherence among concepts in a text are replaced with a condensed and spatially integrated display of line drawings or block figures and design elements, thereby increasing the opportunity of mental linkage formation among verbal labels.

Definitions

A Flow Diagram is a graphic design, composed of descriptive texts, or pictures, or both. Flow diagrams present sequence, identify relations, such as parts to a whole, and explain, rather than represent. A diagram is defined here as evidence of an idea being structured -- it is not *the idea* but a model of it, intended to clarify characteristics of features of that idea. A diagram is a form of communication which increases the pace of development, or allows an idea to function and develop for the thinker while offering the possibility of transfer of an idea or triggering of notions: through appropriate structuring, it may generate different notions and states of mind in the viewer (Dwyer & Dwyer, 1989).

Instructive Questions are questions that are designed to facilitate information organization and serve as adjuncts to presentation types. Two of the four treatment groups in this present study received instructive questions to answer as they studied the presentation material. The instructive questions serve as prompts or information organizers for the content to be learned form the diagram or the texts.

Verbal Chains are specific response associations (Stimulus-Response). Verbal chaining is contingent upon three conditions: "(a) the number of inputs are limited and the stimulus is presented under conditions commanding attention, (b) the response required of the learner is contiguous in time, and (c) the reinforcement as to the correctness or incorrectness of the response is immediate, and correctness procedures are implemented immediately if the initial response is incorrect" (Dwyer & Dwyer, 1989 p. 1). Under these conditions visualization is useful in assisting learners to acquire the basic data-units of

information processing -- facts. Gropper invented the term verbal chaining in his 1970 study on diagram types to describe how the probability of responding is increased. Holliday (1976) adopted the term verbal chaining to compare the teaching effectiveness between flow diagrams and texts.

Research Questions

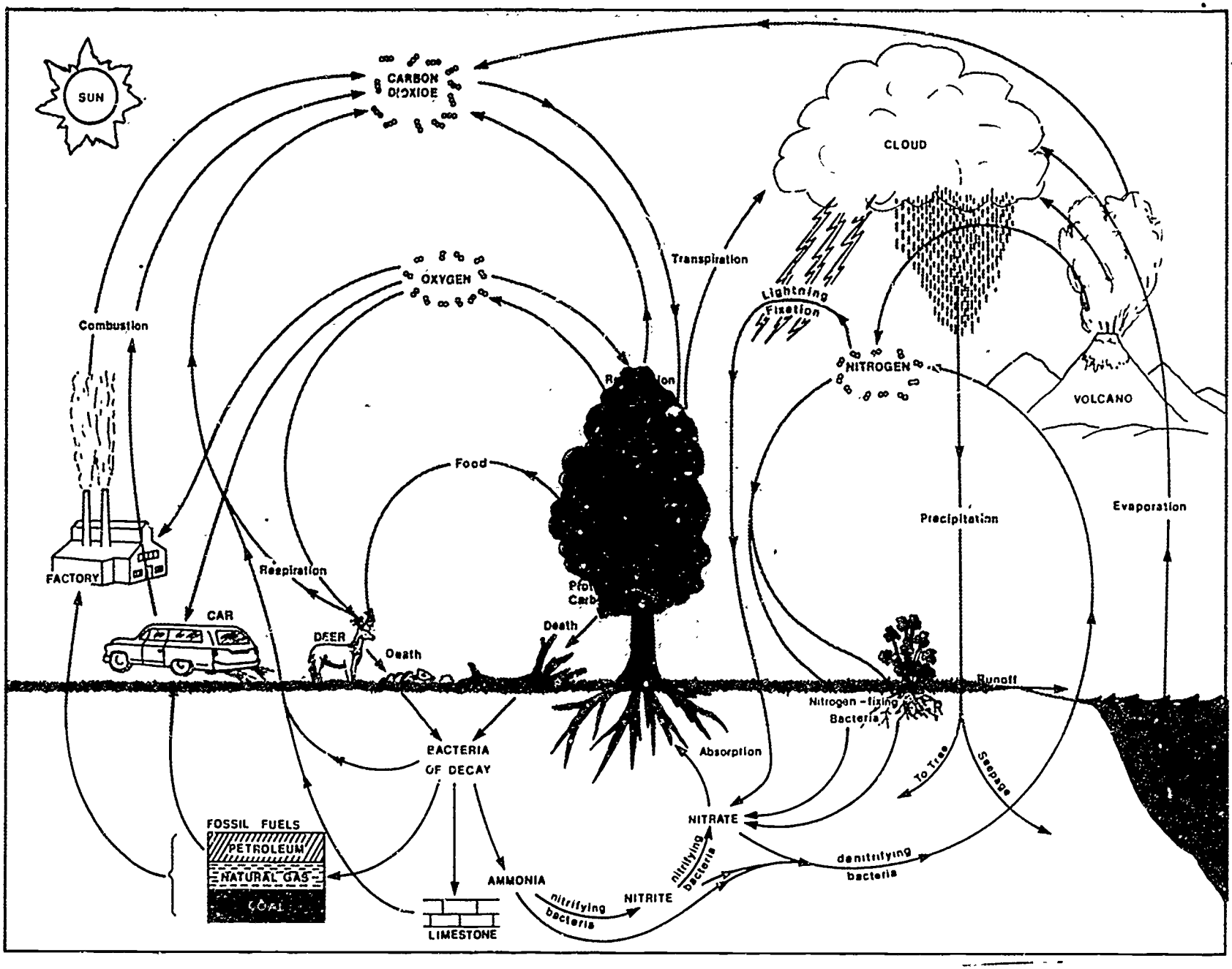
Past visual experiments varied the information contained within the visual, however, this present study varied the information outside the visual. Because the question of the effectiveness of pictures as a medium of communication in instruction is complex, only one factor of pictorial display (flow diagram) was investigated in this study. Flow diagrams are especially helpful for recalling components of a pathway or a cyclic schema and for getting the "big picture" at a glance (Holliday, 1975). Flow diagrams with instructive questions are an effective instructional medium as suggested by Holliday (1976). Although Gropper (1970) and Spangenberg (1971) indirectly support Holliday's (1976) flow diagram with instructive texts theory, and further contend that a flow diagram represents a more effective instructional medium than a text description explaining the same verbal chains, the evidence is inconclusive. Gropper (1970) found that a variety of diagrams with instructive questions was a better learning achievement package than an undefined conventional instruction based on the same objective. Therefore, by utilizing identical information, but, in a textual format, we should be able to more clearly define the attributes associated with pictorial displays. Spangenberg (1971) found that pictorial display groups in controlled experiments performed better than textual display groups due to the degree of integration attributable to pictorial displays. Thus, presenting the main issue that this current study seeks to resolve, that is, are diagrams better than text descriptions when learning verbal chains.

The four major questions are: (1) What is the effect of presentation type (diagram or text) on verbal chain learning?, (2) What is the effect of instructive questions as an adjunct to the presentation type on learning verbal chains? (3) What effect does gender have on the use of diagrams, texts and instructive questions when learning verbal chains? and (4) What effect does college major have on the use of diagrams, texts and instructive questions when learning verbal chains?

Methodology

The participants in this experiment consisted of 129 college students were randomly assigned to one of the four treatment groups. Each participant was asked to study a flow diagram or a text passage, with or without instructive questions, and to take a comprehension test on its content. The first treatment condition (Text Only) required the participants to read a passage composed only of prose which described verbal chains of information. The second treatment condition (Diagram Only) required the participants to study a flow diagram presenting the same verbal chains as the text only condition. The third treatment condition (Text with Instructive Questions) required the participants to answer the instructive questions as they read the textual passage. The fourth treatment condition (Diagram with Instructive Questions) required the participants to answer instructive questions as they studied the flow diagram.

The flow diagram used in this study was a replica of the flow diagram used in previous studies by Holliday (1976, 1981, 1983) which described four, related, scientific pathways or cyclical schemes (see Figure 1). The text passage contained the same information as presented in the diagram. A textual description of the same linkages was typically restricted to the use of nouns, verbs and modifiers and presented in sentence form. An excerpt of the three page text passage is presented in Figure 2. The list of instructive questions used in two of the four treatments was of the "fill-in-the-blank" variety and served as an adjunct or prompt to the diagram or text presentations. The comprehension test (dependent variable) consisted of 24, four-choice items and constituted a content synthesis of two or more of the units displayed in the diagram or presented in the texts.



From "Teaching Verbal Chains Using Flow Diagrams and Texts" by W.G. Holliday, 1976, AV Communication Review, 24, P. 69. Copyright 1976 by Author. Adapted by permission.

Biogeochemical Cycles

Biogeochemical Cycles

Clouds form when moisture in the air condenses on small particles of dust or other solid particles in the air. Moisture from trees and other plant (transpiration) form the clouds. Water vapor that condenses and forms clouds often falls to the earth in the form of rain, sleet, snow, or hail. Water that falls from the atmosphere to the earth is called precipitation. Some water that falls to the earth goes into the ocean through runoff. Some water goes into the ground as seepage. Trees and other forms of plant life use the water.

Oceans play an important part in the hydrologic cycle. During this cycle, the sun's rays heat the surface of the ocean, causing the water to enter the atmosphere as water vapor (evaporation). Seepage and runoff replenish the water of the ocean.

Oxygen in the air contributes to the functioning of trees (plant life), and deer (animal life), through respiration, and by cars (machinery) and factories (industry) through combustion. Plant life provides the main source of oxygen in the air through the process of photosynthesis. While oxygen contributes to the functioning of trees, deer, cars and factories, these same things add carbon dioxide to the air. Carbon dioxide is absorbed by trees and other plant life during photosynthesis.

Figure 2. Excerpt of the three-page text passage. The text passage was used as a single treatment condition and as part of a second treatment condition.

The content accuracy and the degree of information equivalency of the instruments used in this study were validated by a panel of four experts who have taught in the field of Earth Science. The individuals on the panel represented a cumulative teaching experience of 67 years at either high school or college level. The comprehension test produced a Kuder-Richardson reliability coefficient of 0.531.

This experiment used two independent variables: (1) *Presentation Type*, and (2) *the Presence of Instructive Questions*. There was a single dependent variable, the mean score achieved on the comprehension test. This experiment used a posttest-only equivalent group design. The data collected from the participants was analyzed using a 2 X 2 factorial analysis design. An Analysis of Variance (ANOVA) was used to determine statistical significance [Alpha = .05]. Figure 3 illustrates the research design.

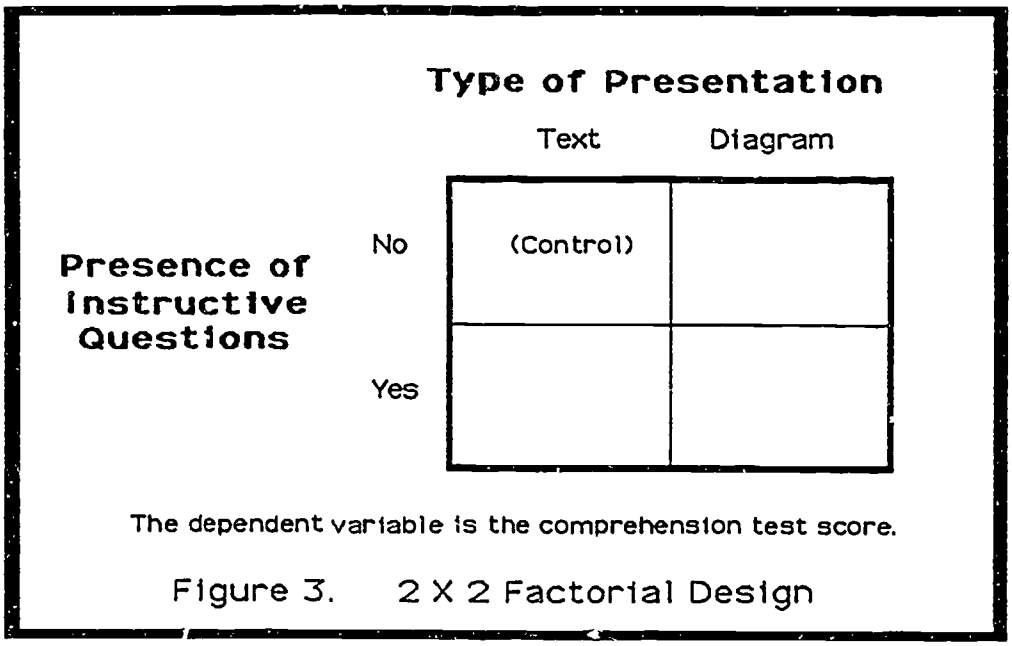


Figure 3. 2 X 2 Factorial Design

Results

The results of the analyses indicated the following:

1. Diagrams are a more effective presentation type than texts.
2. Instructive questions do not enhance learning effectiveness as an adjunct to the two presentation types.
3. There was no differential advantage between presentation type and the use of instructive questions.
4. There was no significant difference in performance across gender.
5. There was no significant difference in performance across education and non-education majors.

Table 1 provides a summary of the mean scores, standard deviations and number of subjects across all treatment groups. Table 2 contains the summary of the 2 X 2 factorial analysis of variance.

Table 1

Summary Table of Means and Standard Deviations by Main Effects N = 129 X = 16.74

Group	n	Mean	SD
Presentation Type			
Diagram	64	17.81	2.81
Text	65	15.69	2.43
Instructive Questions			
With	64	16.11	2.66
Without	65	17.37	2.86
Text Only	33	16.06	2.09
Diagram Only	32	18.72	2.86
Text with Instructive Questions	32	15.31	2.65
Diagram with Instructive Questions	32	16.91	2.36

Note: Maximum possible score = 24.

Table 2

Summary ANOVA Table of Presentation Type and Presence of Instructive Questions

	DF	SS	MS	F	p
Presentation Type	1	145.73	145.73	22.436	.0001**
Instructive Questions	1	52.85	52.85	8.137	.0051*
Interaction	1	9.13	9.13	1.406	.2380
Error	125	811.94	6.50		

* $p < .01$
** $p < .001$

Figure 4 is a graphic presentation of the mean scores for each of the treatment groups.

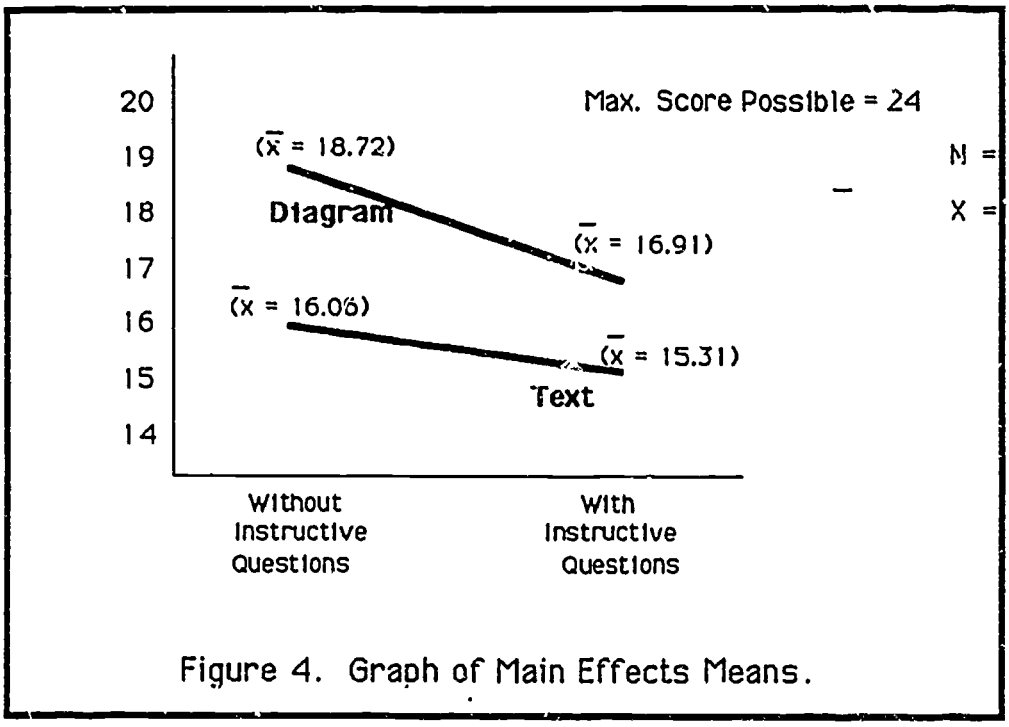


Figure 4. Graph of Main Effects Means.

These results strongly support Holliday's (1976) study of flow diagrams as an effective medium when teaching verbal chains. The first hypothesis of the present study, that flow diagrams are more effective than texts when presenting cyclical information, is accepted. An explanation for this occurrence is that flow diagrams have as a primary attribute the ability to present spatial relationships of entities which reinforce a predicted response (Dwyer & Dwyer, 1989). "We know visualization is capable of: stimulating curiosity, facilitating organization, illustrating data, focusing attention, clarifying information, stimulating interest, raising questions, spanning linguistic barriers, facilitating retention of information, increasing communication reliability, isolating learning cues, facilitating discrimination, introducing new information and initiating discussion" (Dwyer & Dwyer, 1989, p. 2).

The results for this study also favor the overprompting theory (Anderson & Faust, 1967; Anderson, Faust & Roderick, 1968; Faust and Anderson, 1967; Holliday, 1981,1983) which basically states that providing students with strong hints to the answers of questions can do more harm than good. The second hypothesis of the present study which states instructive questions enhance learning effectiveness of the presentation type (diagram or text) is rejected.

The data in this study indicated that student comprehension of verbal chains is inhibited when diagrams are employed together with instructive questions. From the results of the present study, consistent with Holliday's (1981) findings, it is recommended that researchers and teachers be cognizant of the fact that encouraging students to focus selective attention on a sampling of criterial information can result in inadequate processing of such specialized instructional materials as flow diagrams. The use of adjunct questions with flow diagrams is worthy of further investigation with regard to how adjunct questions can be incorporated into instructional methods without interfering with the way students generally study content information.

However, a secondary analysis of the data revealed that of the 129 participants, 103 were females and 26 were males. This raised some questions regarding gender as a confounding variable. It was also noted that 66% of the participants were education majors and thus raising additional questions regarding curriculum as a confounding variable. To answer these questions this study examined the performance of male and female college students, and education and non-education majors when using diagrams or texts with instructive questions to learn verbal chains. Statistical analyses controlling the type I comparisonwise error rate (Duncan's Multiple Range Test) and type I experimentwise error rate (Scheffe's Multiple Range Test) indicate no significant difference in comprehension test scores between male and female participants $F(1,125) = 2.78$, $p > .05$, and no significant difference in comprehension test scores between education majors and non-education majors $F(1,125) = 1.34$, $p > .05$. Therefore, the results indicated by the initial analyses is confirmed.

Conclusions

Media-related researchers need to continue to develop the "broad picture" of flow diagram use in instruction. Diagram type, such as picture-word diagrams (Spangenberg, 1971) or block-word diagrams (Gropper, 1970), diagram complexity, such as word-picture ratio, and diagram resolution are considerations for future research on diagrams.

While we live in an age of visual media, few people learn graphic techniques that apply graphically literate layout strategies. Overhead transparencies, page layouts and bulletin boards usually present a flow of words down the page in straight text or outline form. There is a need to practice more enlightened visual strategies in the classroom by maximizing the use of diagrams (Weisberg, 1970).

Despite the widespread and increasing use of instructional graphics empirical support is needed that will enable diagrams to be effective as a medium on the basis of their instructional qualities rather than on their decorative qualities (Bates, 1981). Flow diagrams have generally

been designed to supplement visually the information presented in texts. We must begin to interpret flow diagrams as an integrated component of a total learning strategy. More evaluation and analysis is still required on how verbal-visual relationships and prior knowledge affect diagram effectiveness. A more informed theoretical understanding of how learners with different levels of prior knowledge relate to varying amounts of descriptive text in diagrams will assist media-related researchers in forming clear criteria for designing efficient diagrams.

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